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(54) Title: A USER POSITIONING TECHNIQUE FOR MULTI-PLATFORM COMMUNICATION SYSTEM
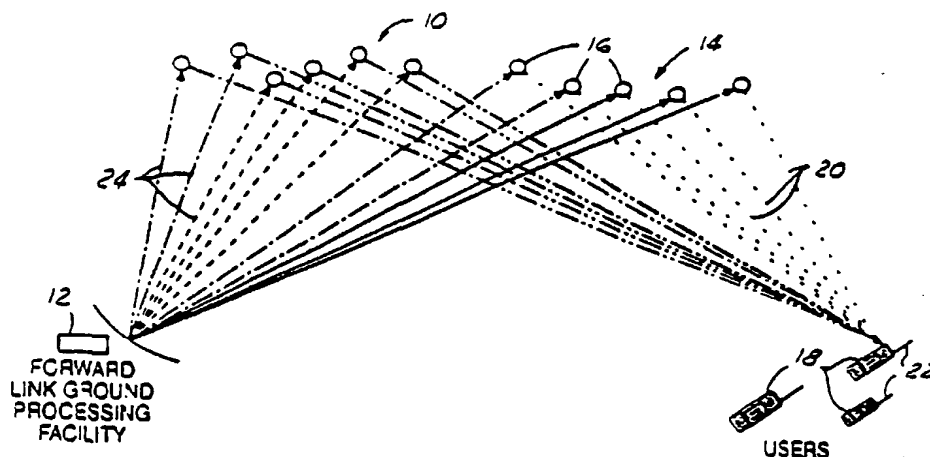
(57) Abstract: A mobile wireless communications system including a plurality of individual transponding nodes all in communi-
cation with a central processing hub. A local user signal is processed by the central processing hub and radiated through multiple
paths to a plurality of the pluralitz of individual transponding platforms simultaneously. The signal is then re-radiated by each of the
plurality of the plurality of individual transponding platforms to a mobile terminal associated with a remote user that receives the
re-radiated signal from the plurality of the plurality of individual transponding platforms coherently and in phase. The number of
transponders and codes used to transmit each user signal can be readily adapted to user requirements. The central hub can determine
the position of each of the remote users based on stored information derived from the synchronization of the various signals, and
specifically relating to the timing, phase or frequency of the signals in both the forward and return link.

A USER POSITIONING TECHNIQUE FOR MULTI-PLATFORM COMMUNICATION SYSTEM

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Cross-Reference To Related Applications

The present application is a continuation-in-part of assignee's co-pending U.S. Serial No.
5   09/271,997, entitled "Multiple Satellite Mobile Communications Method and Apparatus for Hand-Held Terminals," filed on March 18, 1999.

Technical Field

The present invention relates generally to
10 a wireless communication system. More specifically, the present invention relates to a user positioning technique for a multi-platform wireless communication system.

Background Art

15   Current mobile satellite communication systems, such as Iridium, Globalstar, and ICO, utilize low-cost user terminals as one of their key system features. To maintain communications linkage with these current mobile systems, the system
20 satellites provide multiple beam and high-gain services to the subscribers. The low-cost and low-gain hand-held terminals utilized by the users of these systems, transmit and receive signals to and from high performance satellites which populate
25 almost the entire hemisphere. Some of these current systems require access to at least two satellites to

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assure a soft hand-over process as the satellites progress from horizon to horizon. As a result, the satellite system becomes more reliable and available as more satellites come into a user's field of view

5   (FOV). The satellite constellations provided by these current systems are thus sized to guarantee a minimum number of satellites within a user's FOV over large coverage areas at all times.

All of these current mobile satellite

10   communication systems, however, suffer from certain disadvantages. First, they all have limited frequency (the term "frequency" is generalized herein to refer to frequency, time slot or CDMA code) resources. Any given frequency over a given ground

15   position can only be utilized by one user at a time. Thus, if one user accesses a satellite using a particular frequency slot to communicate to his counterpart on network, other satellites and/or users in the same region cannot reuse the same frequency

20   resource in the same local area. In particular, if a nearby secondary user has a handset that requires the same frequency resources as is being utilized by the first user, the second user is unable to access the system, even via different satellites. This is true

25   regardless of the sophistication of the system, including systems that utilize multiple beam satellite designs. Even when multiple satellites are available at a given geographic location, the same frequency spectrum cannot be used by more than one

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user in a local area. The availability of multiple satellites merely serves to increase the availability of the system to the user. However, the total capacity of these mobile communication satellite
5 systems is still limited by their inefficient usage of the available frequency resources. Thus, the potential growth of these current satellite communication systems is inherently limited.

Additionally, current telecommunications
10 systems generally allow only mobile-to-hub and hub-to-mobile communications in most low earth orbit and medium earth orbit mobile satellite constellations. Mobile-to-mobile linkages require multiple hops between hubs. This means that two or more frequency
15 resources must be committed by the system to close the links.

It is clearly desirable to provide a mobile communication satellite system that relaxes the above
20 constraints, and more efficiently utilizes current mobile satellite communication system resources, while also providing much greater opportunity for system growth.

Summary of the Invention

25   It is an object of the present invention to provide a wireless communication system with reduced

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limitations on frequency re-use for point-to-point communications.

It is another object of the present invention to provide a wireless communication system that utilizes individual transponders and mobile terminals that are relatively simple and of low complexity.

It is a further object of the present invention to provide a wireless communication system with high system reliability through graceful degradation.

It is still another object of the present invention to provide a multi-transponder wireless communication system that allows flexible combination of user types.

It is a related object of the present invention to provide a multi-transponder wireless communication system with better utilization of total system resources.

It is yet a further object of the present invention to provide a user positioning technique for a multi-platform system that increases the total monetary return.

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In accordance with the above and other objects of the present invention, a multi-platform wireless communication system is provided. The wireless communication system includes a plurality of
5   individual communication transponding nodes. The plurality of individual transponding nodes are each in communication with a ground hub such that a signal processed by the ground hub in the forward link is radiated with compensating time delays to one or more
10   of the plurality of individual transponders. The radiated signals are then re-radiated by the plurality of individual transponders and coherently received and processed by a mobile user terminal. The return link signal path is the reverse of the forward
15   link.

In accordance with another object of the present invention, the system includes a plurality of individual transponding nodes. The system also
20   includes a plurality of mobile terminals each associated with a respective remote user. A central hub establishes a link with one or more of the plurality of mobile terminals through one or more of the plurality of transponding nodes. The central hub
25   processes one or more local user signals from one or more of the remote users and synchronizes the one or more local user signals such that an intended user receives all signals synchronously and in phase. The central hub can then determine the position of each
30   of the remote users based on the information stored

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on the central hub regarding the timing, phase, or
frequency of signals in both the forward and return
links.

5   The system further includes a plurality of
individual resource cells, each associated with a
particular one of the plurality of individual
transponding nodes and a particular on e of the
plurality of available codes. The system further
10   includes a plurality of mobile terminals of different
types, each of which is assigned to operate in one or
more of the plurality of individual resource cells.

These and other features of the present
invention will become apparent from the following
15   description of the invention, when viewed in
accordance with the accompanying drawings and
appended claims.

Brief Description of the Drawings

FIGURE 1 is a schematic illustration of the
20   forward link geometry of a mobile satellite
communications system in accordance with the present
invention;

FIGURE 2 is a schematic block diagram
illustrating the signal transmission function of a
25   ground telecommunications hub for a wireless

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communications system in accordance with a preferred
embodiment of the present invention;

     FIGURE 3 is a schematic illustration of the
return link geometry of a wireless communications
5   system in accordance with a preferred embodiment of
the present invention;

     FIGURE 4 is a schematic block diagram
illustrating the signal receive function of a ground
telecommunications hub for a wireless communications
10   system in accordance with a preferred embodiment of
the present invention;

     FIGURE 5 is a schematic flow diagram
illustrating the overall architecture for a wireless
communications system in accordance with a preferred
15   embodiment of the present invention;

     FIGURE 6 is a schematic illustration of a
multi-transponder wireless communication system
illustrating signals being received coherently by
20   their intended remote user;

     FIGURE 7 is a schematic illustration of the
multi-transponder wireless communication system of
Figure 6 illustrating the same signals being received
25   incoherently by a remote non-intended user;

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        FIGURE 8 is a schematic illustration of a
conventional approach to an asynchronous CDMA system
that may be utilized in accordance with the present
invention; and

5

        FIGURE 9 illustrates a preferred embodiment
of the present invention applied to the asynchronous
CDMA system of Figure 8.

10   **Best Mode(s) for Carrying Out the Invention**

        Referring now to the figures, the disclosed
mobile communication system can be utilized to break
away from the frequency spectrum limitation discussed
above and provide much more efficient means to re-use
15   the allocated mobile satellite and wireless spectrum
multiple   times.   By   eliminating   this   frequency
spectrum   limitation   on   the   operation   of   multiple
satellites,   the   overall   capacity   of   existing   mobile
satellite and wireless communication systems can more
20   readily expand.

        Referring   now   to   Figure   1,   a   mobile
satellite communication system 10 in accordance with
a preferred embodiment of the present invention is
25   illustrated.   In   Figure   1,   the   mobile   satellite
communications system 10 is illustrated in a forward
link mode.   The   mobile   satellite   communications
system 10 includes a ground telecommunications hub

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12, a satellite constellation 14 including a plurality of individual satellites 16, and a plurality of hand-held user terminals 18 such as mobile phones. As discussed in more detail below,
5 the user terminals 18 can receive signals 20 simultaneously from multiple satellites 16 via their broad beam antennas 22. The ground telecommunications hub 12 is in communication with all of the satellites 16 in the satellite
10 constellation 14 individually and simultaneously. The hub 12 also pre-processes user signals to compensate for path differentials before sending radiated signals 24 to the satellites 16, as discussed in more detail below.

15   In accordance with the preferred embodiment, the design of the individual satellites 14 can be significantly simplified over those utilized in prior mobile systems because the satellite constellation 14 functions as a sparse
20 radiating array. It is known that the more satellites 16 that are included in a satellite constellation 14, the better the performance the mobile satellite communications system 10 will achieve. Satellites that are simple, small, and
25 provide high performance are preferable. This is because the performance of the system 10 depends more heavily on the satellite constellation 14 than on the individual satellites 16.

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In a transmit mode, shown in Figure 1, the individual satellites 16 radiate modulated RF power to a chosen field of view ("FOV"). The system 10 is still operable with reduced capacity and no reconfiguration even if one individual satellite 16 is lost for any reason. As a result, the system 10 features graceful degradation characteristics and provides very high reliability and availability. Most of the complexity of the system 10 is located in the ground hubs 12, which locate and track the potential users and perform the major functions of beamforming and filtering, as discussed below.

As shown in Figure 2, the processing performed at the ground telecommunications hub 12 is diagrammatically illustrated. The hub 12 tracks, updates, and forward predicts the time variant differential information among various paths between the hub 12 and the intended user terminals 18. The accuracy of this information must be within a tenth of an RF wavelength. For UHF satellite systems, the required path differential accuracy is preferably about ten (10) centimeters. For L and S band mobile satellite constellations, the accuracy must be on the order of one (1) centimeter. Unfortunately, the conventional or GPS techniques are not able to provide the required accuracy.

In accordance with the present invention, the required accuracy of the equivalent path

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differentials, including all propagation distortion, can be provided using two-way active calibration and R2N (two-way ranging navigation) techniques. An R2N technique is just one technique for obtaining

5   positioning information by which to locate the positioning of the satellites and users precisely using multiple calibration sites and is described in co-pending U.S. Patent Application Serial No. 09/209,062, entitled "Method and System for

10   Determining a Position of a Transceiver Unit Incorporating Two-Way Ranging Navigation as a Calibration Reference for GPS," and filed on December 10, 1998. Other known techniques may also be utilized.

15   The ground telecommunications hub 12 has a processing center 26 that processes each signal and is shown in a transmit mode in Figure 2. The hub 12 has the capability to address the plurality of satellites 16 individually through the use of antenna

20   spatial discrimination to provide separate signals to different satellites. Alternatively, code identification can also be used to address different satellites independently.

         As shown in Figure 2, assuming that there

25   are "H" users, the signals from user 1 to user H, identified generally by reference number 28, are input into the processing center 26. The position of the various users (1 to H), are determined generally

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by the circuitry from the various user signals 28, designated by reference number 30. The various user signals 28 for user 1 to user H are then combined for transmission to the different satellites 16, as
5   generally indicated by reference number 32. In this case, the signal is sent to N satellites. The combined signals are then amplified, filtered, up converted, and then further amplified, as generally indicated by reference number 36. These signals are
10   then delivered to a multiple beam antenna 38 where beam-forming processing is done so that the signals can be transmitted to the N satellites via radiating signals 24. The beam-forming process can be done in baseband or a low IF frequency band by either digital
15   or analog means. For a low bandwidth (less than a few MHz signals), digital implementation can provide cost advantages. The processed signal 24, radiated from the ground hub 12 to each satellite, is amplified, filtered, and then re-radiated by each of
20   the multiple satellites 16 to arrive at a designated user location simultaneously. Consequently, the radiated signals from the multiple satellites will be received coherently by a simple hand held terminal 22.

25   Equivalently, the effect of the spatial processing performed by the processing center 26 is to focus signal strength on the user from multiple satellites 16, which act like sparsely separated portions of a large active reflector. Therefore, the

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processing on the ground will insert different time delays into the signals 24 which are radiated via various paths. The time delays will be inserted into the signals 24 as if the satellites were located on
5 an ellipsoidal surface, of which the two foci are located exactly at the hub 12 and the designated user 18 positions respectively. In low and middle earth orbit constellations, the users 18 and the hub 12 will always be in the near field of the sparse array.

10   In a receive mode, shown in Figure 3, the individual satellites 16 collect RF signals from the same FOV. Figure 3 illustrates the return link geometry for receiving signals sent from the user terminals 18 to the ground telecommunications hub 12.
15 As shown in Figure 3, there are two groups of links involved: the links between users 18 and the satellites 16, generally indicated by reference number 40, and those between the satellites 16 and the hub 12, as generally indicated by reference
20 number 42. For best performance, the user antennas 22 preferably are able to illuminate all the satellites 16 involved. This will lead to a constraint on the variation of the gain of the user antenna 22 over the cluster.

25   As with the forward link geometry, the satellites 16 will amplify the signals 40 received from the users 18 and re-radiate the signals 42 toward the hub 12. The hub 12 can receive signals 42

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independently, but simultaneously from the satellites 16, and will add the signals 42 from different satellites coherently in the post-processor 44 as illustrated in Figure 4.

5   The signal flows on the block diagram shown in Figure 4 illustrate the receive function of the post-processor 40 and the hub 12. The signal flows are reversed from the corresponding ones in Figure 2. Therefore the receive process will not be reiterated 10   in detail. However, the links 42 from the satellites 16 to the hub 12 are received at the beamformer 38 and then transferred to the receiver and down converters 46 before the signals are separated. The signals are separated depending upon the user from 15   which they are received, as generally indicated by reference number 48, and then sent to the specific user 1 through H, as generally indicated by reference number 50. It should be understood that both the receive and transmit function are a necessary part of 20   the pathlink calibration and user positioning.

The technique of the present invention has been demonstrated to significantly reduce the average side lobe levels. It has been determined that this is due to three factors. First, the proposed 25   architecture is not a periodic array, but rather a randomly spaced sparse array, which has no grating lobes. Although the average side lobe level at a single frequency is relatively high, the level

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decreases with increasing bandwidth. Second, the large sparsely filled array formed by moving satellites is a large extended aperture size. Thus, all of the users on the ground are in the near field
5 of the extended aperture and the wave fronts received by all users are spherical instead of planar. Consequently, dispersion effects become much more pronounced than would be the case in the far field. The dispersion grows very fast as a probe is scanned
10 away from the main beam and the dispersion smears the power distribution very effectively over a finite signal bandwidth. Third, the communication system is preferably designed with a large frequency bandwidth spectrum. The information signal will therefore be
15 spread over this bandwidth via CDMA or through short duration waveforms for TDMA schemes.

Figure 5 illustrates diagrammatically the operation of the invention, which allows for the increased re-use of precious frequency spectrum by
20 multiple satellites. The advantages provided by this system include no limitation on frequency re-use by additional satellites for point-to-point communications. Rather, the capacity of this system is only limited by total satellite RF power.
25 Further, the preferred embodiment allows for the use of simple and low cost satellite designs, because the more satellites included in the constellation, the better the performance of the overall system. The system also provides high system reliability through

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graceful degradation, as well as concentrating complex processing at the hubs.

The preferred embodiment creates demand for a large number of low cost satellites and also uses R2N techniques to perform satellite and user positioning. The more users using this system, the more accurately the satellite and user positions can be determined. However, even more important than the actual positions of the users and satellites are the path lengths traversed by the signals. Therefore, periodic calibration techniques applied directly to those path lengths may be much simpler and more cost effective. Further, the system also benefits from large percentage bandwidths available with CDMA and TDMA systems.

As shown in Figure 5, the present invention is divided up into three segments: a hub segment 52 containing the ground telecommunications hub 12, a space segment 54 containing a plurality of individual satellites 16, and a user segment 56, having a plurality of user terminals 18. The hub segment also has a processing center 26 and a post-processor 44 for processing the received and transmitted signals.

The user terminals 18 receive and transmit signals simultaneously from/to multiple satellites 16 via their broad beam antennas. The user terminals 18 do not require any capability to separately address

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the individual satellites 16 of the space segment 54.
The hub 12 maintains links with each of the
satellites 16 in the space segment 54 individually
and simultaneously.   The hub 12 pre-processes the
5   signals intended for each remote user on transmission
and post-processes the signals supplied to each local
user   on   reception   to   compensate   for   path
differentials.   These corrections are separately
computed and applied to the signals transmitted to or
10   received from each satellite 16 of the space segment
54 for each user.

     Figure   6   illustrates   a   multi-platform
communication system 100 with improved frequency
reuse efficiency in accordance with a preferred
15   embodiment of the present invention. In particular,
the system illustrated in Figure 6 uses CDMA coding
to subdivide the frequency resource among the various
users.   The system 100 enables a plurality of
transponders 102, 104 to receive signals 106, 108
20   from the ground hub 110 and to transmit the signals
112, 114 at the same frequency with reduced
interference to the intended user 116 from signals
intended for other users.   This is achieved by
synchronizing the transmitted signals at the hub in
25   such a way that the intended user 116 will receive
all of the signals 112, 114 synchronously and
completely in phase.

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Based on the distances from the hub 110, to
the various transponders 102, 104 and the distances
between the transponders 102, 104 and the intended
user 116, the appropriate compensating time delays
5   are calculated and injected into each forward link
message at the hub such that the intended user will
coherently receive a combined signal from all the
transponders as generally indicated at 118. The
forward link to the intended user 116 follows the
10   sequence of the hub 110 to the first transponder 102
to the user 116 (hub → trans 1 → user 1) and also
from the hub 110 to the second transponder 104 to the
user 116 (hub → trans 2 → user 1). Using the
correct time delay on each forward link, all intended
15   signals 112, 114 will arrive at the intended user 116
in phase. Conversely, the same signals intended for
the intended user 116 will arrive out of phase at a
non-intended user 120 and all other non-intended
users in the area. This is shown in Figure 7, which
20   is described below.

Figure 7, illustrates the operation of the
system of Figure 6 with respect to the non-intended
user 120. The distance between the hub 116 and the
25   first transponder 102 and the distance between the
first transponder 102 and the non-intended user 120
(hub → trans 1 → user 2) and the distance between
the hub 116 and the second transponder 104 and the
distance between the second transponder 104 and the

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non-intended user 120 (hub → trans 2 → user 2) are different in this case, even after compensation by the hub. Because of the distance differences, the signals 122, 124 will arrive at the non-intended user
5   120 at a different times and out-of-phase.   The combined signal 126 will thus appear as noise and can be rejected as such by the terminal of the non-intended user 120.

10   It should be understood that the transponders 102, 104 can be part of any type of wireless communication system or can even be selected from several such systems.   For example, while a space based system using satellites is illustrated,
15   regional and national tower-based cellular networks for fixed and mobile communications may also be utilized.   Additionally, any high altitude platform system, such as manned/unmanned airships, balloons, or airplanes may also be utilized.   Further, while
20   only two transponders are illustrated, an unlimited number of transponders may be utilized.   Moreover, while the multiple transponders are shown as being part of a unitary system, any combination of transponders can be used to transmit signals in
25   accordance with the present invention.   For example, a signal may be transmitted to a user through both a space-based system and a high altitude platform system. Finally, different sets of transponders may be used to communicate with different users.   These

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various sets may overlap in whole, in part or not at
all.

5   As is known, in conventional CDMA single
transponder systems, unique CDMA codes are assigned
to each user to avoid interference. Similarly, in
multi-transponder   systems,   when   two   or   more
transponders   are   serving   the   same   geographical
location,   unique   CDMA   codes   must   be   used   to
10   distinguish   the   various   signals   and   to   avoid
interference.   For example, as shown in Figure 8,
which   illustrates   a   conventional   CDMA   multi-
transponder system, user 116 must use different codes
for signals 112, 114 received from the two different
15   transponders 102, 104.   Thus, two distinct codes,
"code 1" and "code 3" are assigned to the same user
116 in this example, with "code 1" being assigned to
signal 112 and "code 3" being assigned to signal 114.
If both transponders 102, 104 were to transmit at
20   "code 1", the two received signals 112, 114 would
interfere with each other and the terminal of the
user 116 would not be able to decode the signals
correctly.   Two additional codes must be assigned to
each   additional   user,   such   as   user   128   who   is
25   assigned codes 2 and 4.

         The various CDMA codes for co-located users
can be synchronous or asynchronous.   A synchronous
orthogonal code gives an advantage of about 15 dB or
30   better over asynchronous CDMA codes.   For multiple

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platforms, it is hard to synchronize CDMA codes among users.   Thus,   for   the   disclosed   multi-platform system, asynchronous CDMA communication is assumed. Although multiple transponder nodes increase the
5   system availability and total power resource, it under-utilizes the system's full potential, because there are only a finite number of codes available due to the finite bandwidth available to a system.   Thus, the total bandwidth limits the number of users the
10 system can serve and the system is unable to fully utilize the power and capacity it was designed to handle.

         In the preferred embodiment, the system 100
15 is an asynchronous CDMA system that utilizes imbedded time   delays   as   described   in   co-pending   patent application   Serial   No.   _09/550,505_   ,   filed _April 17, 2000_   and entitled "Coherent Synchronization. of Code Division Multiple Access Signals," which is
20 hereby incorporated by reference. In accordance with the preferred system, the signals 112, 114 from each transponder 102, 104 will arrive completely in-phase because appropriate time delays are pre-determined and applied to the signals 112, 114 at the central
25 hub 100, as is shown in Figure 9.   It should be understood that other time delay methods can also be utilized.

         As   shown,   the   first   user   116   receives
30 signals 112 from each of the transponders 102, 104

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using the same code ("code 1"). Similarly, the
second user 128 receives signals 114 from each of the
transponders 102, 104 using the same code ("code 2").
The central hub 110 determines the time delay between
5   the users and the hub for signals transmitted or
received via each transponder and inserts appropriate
delays to equalize the total delay via each
transponder. Thus, the intended signals from
different transponders will all arrive at the
10 intended user in-phase, while non-intended signals
will arrive out of phase.

The multi-platform system 100 synchronizes
all platforms or transponder nodes 102, 104 in
15 reference to each user 116 of the system. This
synchronization process involves techniques and
procedures to synchronize at least three parameters,
including timing, phase, and frequency of signals in
both the forward link and the return link. The bulk
20 of the required processing to accomplish this
synchronization is performed at the central hub 110.

In accordance with a preferred embodiment,
the results of the synchronization process can be
25 used to assist in a determination of user position.
Through this technique, certain data that has been
obtained during the normal synchronization operation
can be used to provide information about user
positioning that will allow the system to operate in
30 a manner that is more profitable and generates

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additional revenues. This technique can be accomplished without requiring the dedication of additional resources from the space segment 54 or the user segment 56.

Three key parameters that are synchronized by the central hub 110 include timing, phase, and frequency. Further, in accordance with the preferred technique, the following parameters are utilized:

$\vec{R}_{pi}$ Relative position vector of user with respect to platform i.

$\dot{\vec{R}}_{pi}$ Relative velocity vector of user with respect to platform i.

r_{pi} Range of user with respect to platform i.

$\dot{r}_{pi}$ Range rate of user with respect to platform i.

$\begin{pmatrix} x \\ y \\ z \end{pmatrix}$ Unknown position vector of user.

$\begin{pmatrix} x_{pi} \\ y_{pi} \\ z_{pi} \end{pmatrix}$ Known position vector of platform i.

n_p Number of platforms in the system

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In order to describe the operation of the preferred user positioning method, the user position vector to be determined is assumed to be:

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix}$$

It is assumed that the positions of the platforms 102, 104 are known. Therefore, unknown ranges of the user are determined as follows:

$$r_i^2 = (x - x_{pi})^2 + (y - y_{pi})^2 + (z - z_{pi})^2$$

As discussed above, the synchronization process requires the use of a timing delay of the signal along both the forward and return links. The timing delay parameter is proportional to range, thus, the above set of equations results in n_p equations with three unknowns: x, y and z. When n_p is greater than three (3), then there is a larger number of measurements than are needed to determine the unknown user position. If n_p is less than three, this information is still useful for determining user positions when combined with beam direction information in the case of single platform system.

The frequency parameter information from synchronization can also be used to establish more user positioning information. The frequency measurement is proportional to range rate and is thus

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related to the unknown user position in accordance
with the following equation:

$$r_i \dot{r}_i = \left(x - x_{pi}\right)\left(\dot{x} - \dot{x}_{pi}\right) + \left(y - y_{pi}\right)\left(\dot{y} - \dot{y}_{pi}\right) + \left(z - z_{pi}\right)\left(\dot{z} - \dot{z}_{pi}\right)$$

This provides an additional set of equations when it
5   is assumed that the position rate can be determined
from a position change with respect to time.

        The   final   synchronization   parameter   is
phase,   which   also   contributes   information   to   user
10   positioning, but in a highly non-linear, modular way.
The determined phase is related to range as follows:

$$\text{phase} \approx r_i \bmod \lambda$$

        The   parameters   derived   in   the
15   synchronization   process   of   the   operation   of   the
multi-platform system 100, are thus used to determine
the   user   position   without   the   need   to   collect
additional data.   The preferred method thus tracks
the user's position on the system 100 and monitors
20   the   time   delays   for   signals   transmitted   to   and
received from any user.   The system 100 can thus
adjust the time delays depending upon the coherency
of the signals.   For any given user there may be any
number of different time delays.   Thus, based on the
25   user   positioning   information,   the   time   delay
estimates can be modified.   This thus allows for the
additional utilization of the information that are
already available to increase the profitability of
the system.

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        Having now fully described the invention,
it will be apparent to one of ordinary skill in the
art that many changes and modifications can be made
5   thereto without departing from the spirit or scope of
the invention as set forth herein.

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In The Claims:

1   1.   A   method   for   determining   user
2   position, comprising:
3   providing   a   plurality   of   individual
4   transponding nodes;
5   establishing   one   or   more   links   from   a
6   central processing hub with at least one remote user
7   through one or more of said plurality of transponding
8   nodes;
9   processing   at   least   one   local   user   signal
10   at a ground hub, such that the timing, phase, and
11   frequency of signals in both the forward and return
12   links with respect to said at least one remote user
13   are synchronized for all intermediate transponding
14   nodes; and
15   determining   the   range   of   at   least   one
16   remote user utilizing said timing information stored
17   at said central hub.

1   2.   The   method   of   claim   1,   further
2   comprising:
3   providing additional information about the
4   position of said at least one remote user based on
5   the frequency information stored at said central hub.

1   3.   The   method   of   claim   2,   further
2   comprising:

3   assisting in determining the position of

4   said at least one remote user based on the phase

5   information stored at said central hub.

1   4.   The method of claim 1, wherein the

2   range is related to the user position by the

3   following equation:

4            $r_i{}^2 = (x - x_{pi})^2 + (y - y_{pi})^2 + (z - z_{pi})^2$

1   5.   The method of claim 2, wherein the

2   user position is further conditioned by the following

3   equation:

4       $r_i \dot{r}_i = \left(x - x_{pi}\right)\left(\dot{x} - \dot{x}_{pi}\right) + \left(y - y_{pi}\right)\left(\dot{y} - \dot{y}_{pi}\right) + \left(z - z_{pi}\right)\left(\dot{z} - \dot{z}_{pi}\right)$

1   6.   The method of claim 3, wherein further

2   user positioning information is provided based on the

3   following equation:

4            $phase \approx r_i \bmod \tau$

1   7.   A mobile wireless communication system

2   with accurate user positioning capabilities,

3   comprising:

4   a plurality of individual transponding

5   nodes;

6   a plurality of mobile terminals each

7   associated with a respective remote user;

8   a central hub for establishing links with

9   one or more of said plurality of mobile terminals,

10   each through one or more of said plurality of

11   transponding nodes;

12   said central hub processes one or more

13   local user signals from one or more of said remote

14   users and synchronizes said one or more local user

15   signals such that an intended user receives all

16   signals synchronously and in-phase;

17   whereby said central hub can determine the

18   position of each of said remote users based on

19   information stored on said central hub regarding the

20   timing, phase and/or frequency of signals in both the

21   forward and return link.

1   8.   The system of claim 7, wherein said

2   central hub uses information about the timing of user

3   signals to assist in determining the position of said

4   user.

1   9.   The system of claim 8, wherein said

2   user position information is determined according to

3   the following equation:

4             $r_i^2 = (x - x_{pi})^2 + (y - y_{pi})^2 + (z - z_{pi})^2$

1   10.   The system of claim 7, wherein said

2   central hub uses information about the frequency of

3   user signals to assist in determining the position of

4   said user.

1   11.   The system of claim 10, wherein said

2   user position information is determined according to

3   the following equation:

4        $r_i \dot{r}_i = \left(x - x_{pi}\right)\left(\dot{x} - \dot{x}_{pi}\right) + \left(y - y_{pi}\right)\left(\dot{y} - \dot{y}_{pi}\right) + \left(z - z_{pi}\right)\left(\dot{z} - \dot{z}_{pi}\right)$

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1   12. The system of claim 7, wherein said
2   central hub uses information about the phase of user
3   signals to assist in determining the position of said
4   user.

1   13. The system of claim 12, wherein said
2   user position information is determined according to
3   the following equation:
4           $phase \approx r_i \bmod \tau$

1   14. The system of claim 7, wherein said
2   central hub uses information about the timing, phase
3   and frequency of user signals to assist in
4   determining the position of said user.

1   15. A method for determining the position
2   of a mobile user, of a wireless communication system,
3   comprising:
4   providing a plurality of mobile users;
5   establishing links between each of said
6   plurality of mobile users and a ground hub through
7   one or more of a plurality of transponding nodes;
8   processing a plurality of local user
9   signals at said ground hub such that signals are
10   delivered to an intended user coherently and in
11   phase; and
12   determining the position of a mobile user
13   based   on   information   retrieved   from   the
14   synchronization of the respective local user signals
15   and stored on said central hub as timing, phase,

16   and/or frequency information relating to said local
17   user signals.

1   16. The method of claim 15, wherein said
2   determining includes gathering information about the
3   position of said mobile user based on frequency
4   information.

1   17. The method of claim 15, wherein said
2   determining includes gathering information about the
3   position of said mobile user based on timing
4   information.

1   18. The method of claim 15, wherein said
2   determining includes gathering information about the
3   position of said mobile user based on phase
4   information.

1   19. The method of claim 15, wherein said
2   determining includes gathering information about the
3   position of said mobile user based on any combination
4   of information from each of said timing, phase, and
5   frequency.

1   20. The method of claim 15, wherein each
2   of said plurality of individual transponding nodes is
3   independently selected from one of the following
4   system types: a space-based system, a high altitude
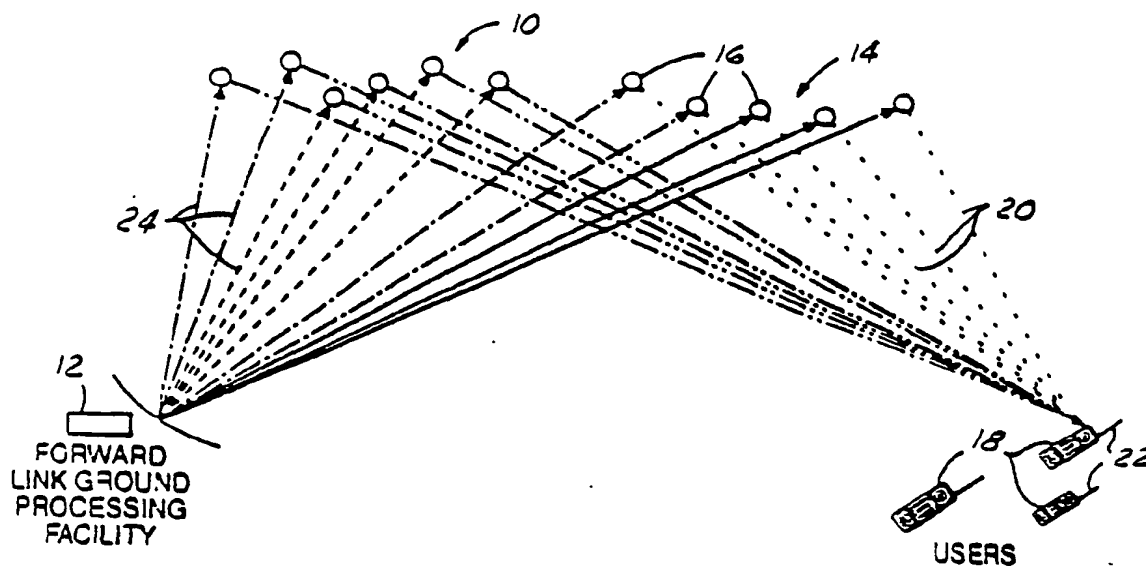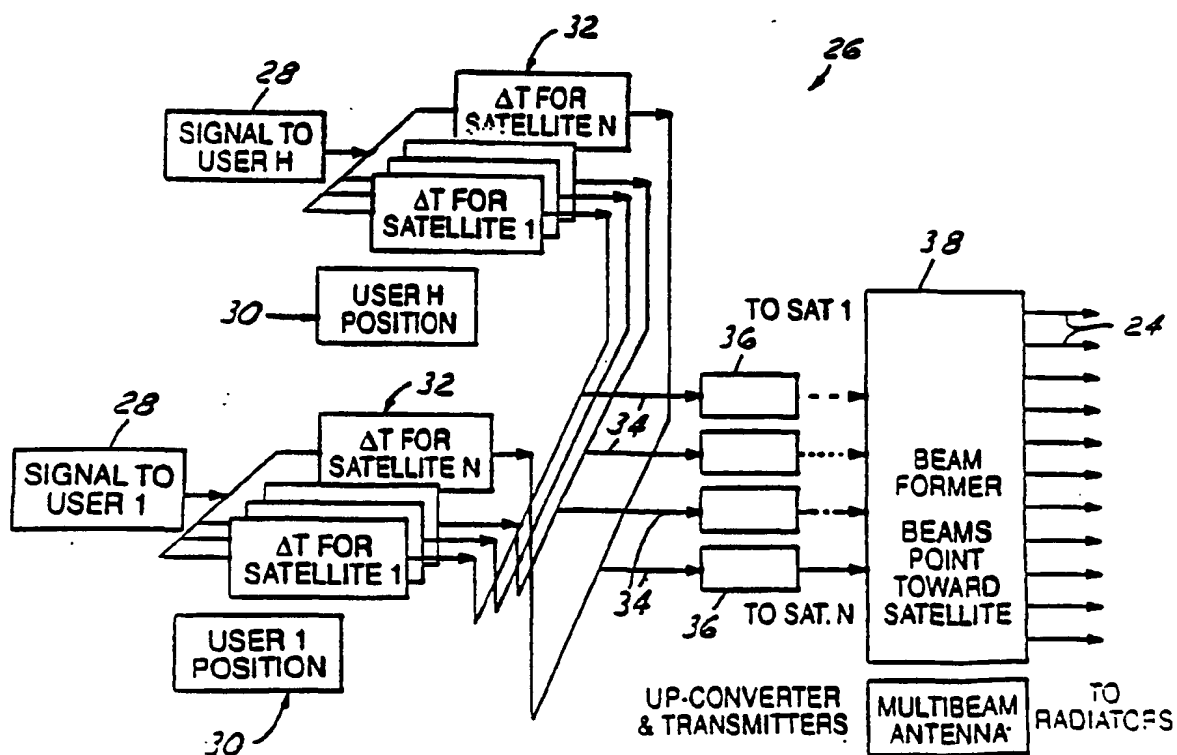5   platform system, or a tower based cellular network.

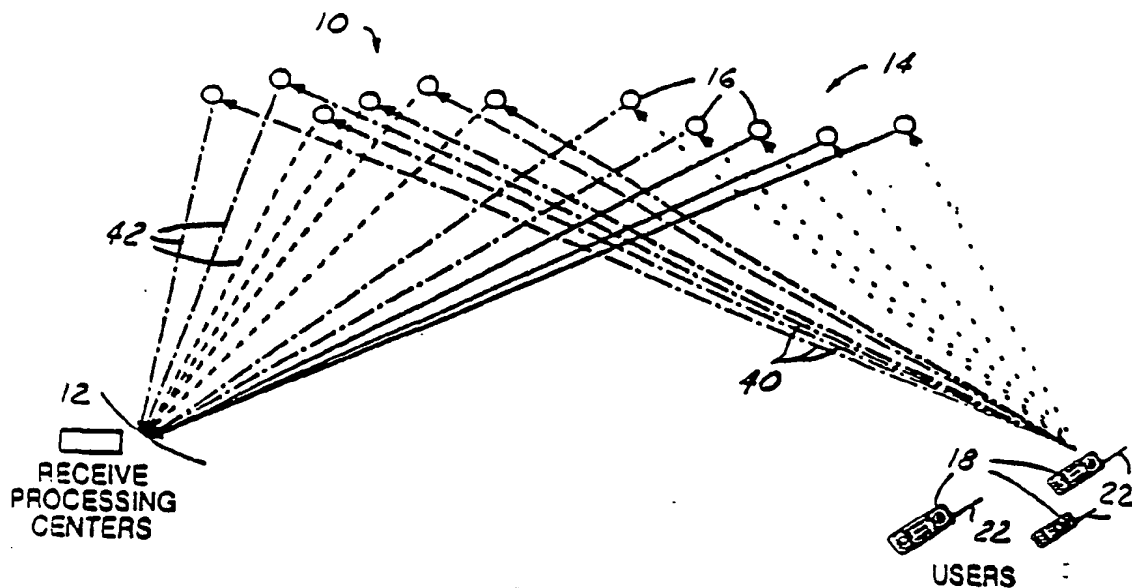FORWARD LINK GROUND PROCESSING FACILITY

USERS

FIG.1

SIGNAL TO USER H

ΔT FOR SATELLITE N

ΔT FOR SATELLITE 1

USER H POSITION

SIGNAL TO USER 1

ΔT FOR SATELLITE N

ΔT FOR SATELLITE 1

USER 1 POSITION

TO SAT 1

TO SAT. N

UP-CONVERTER & TRANSMITTERS

BEAM FORMER

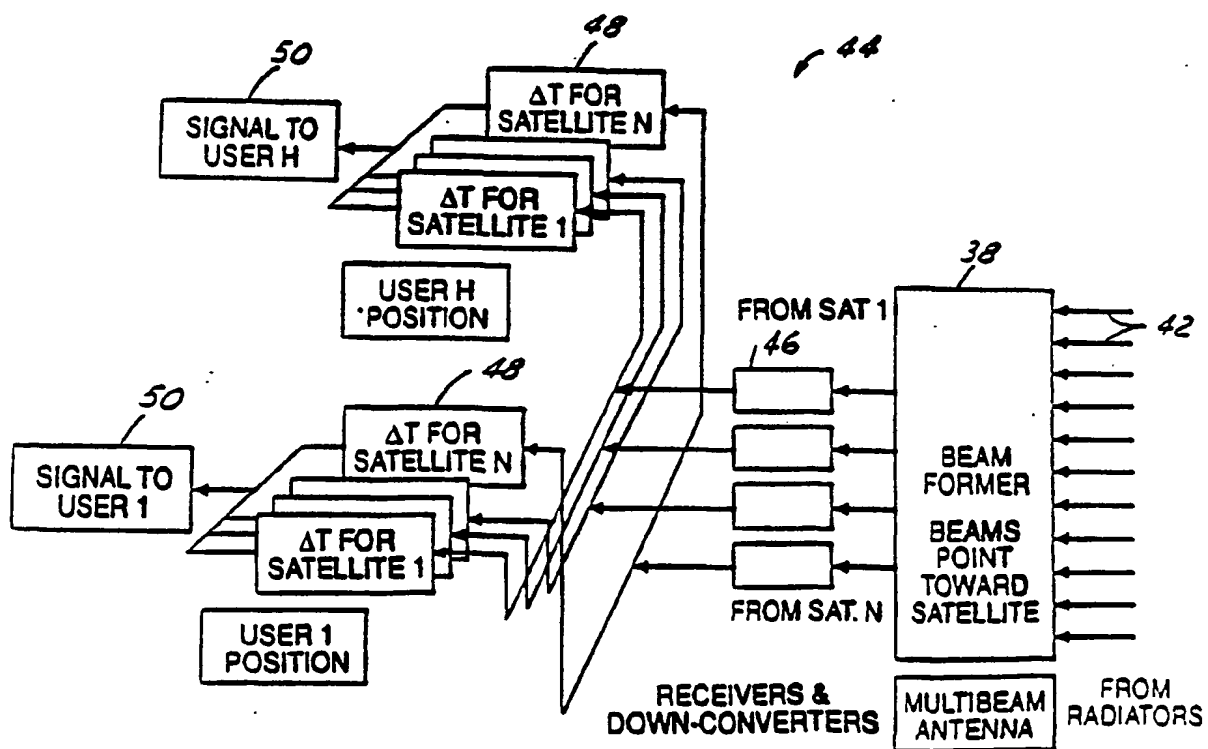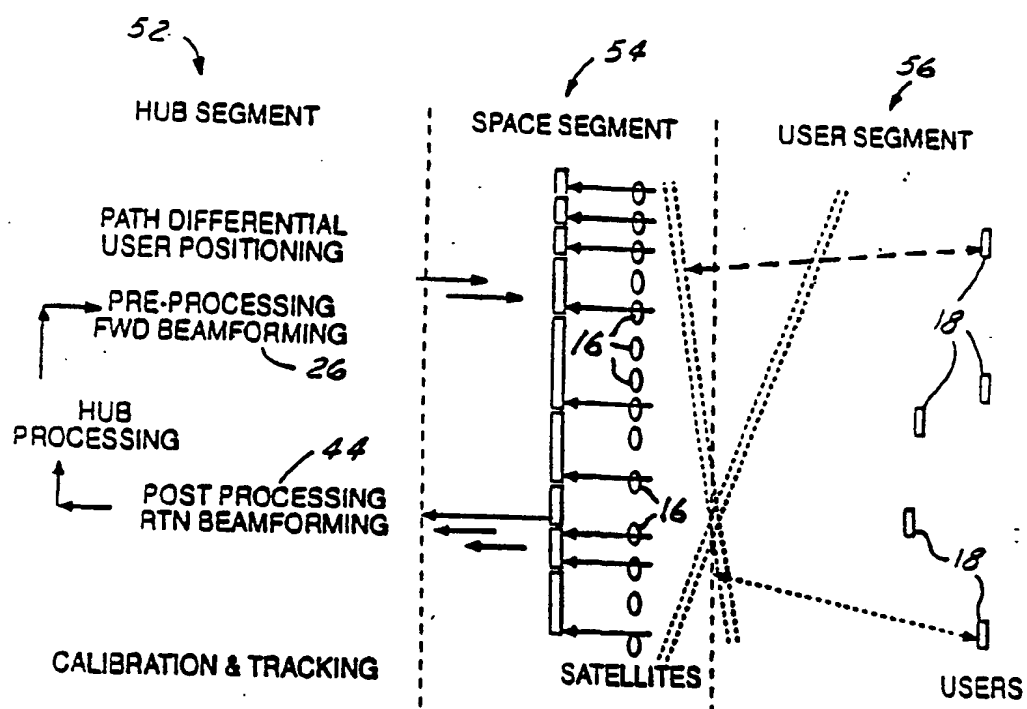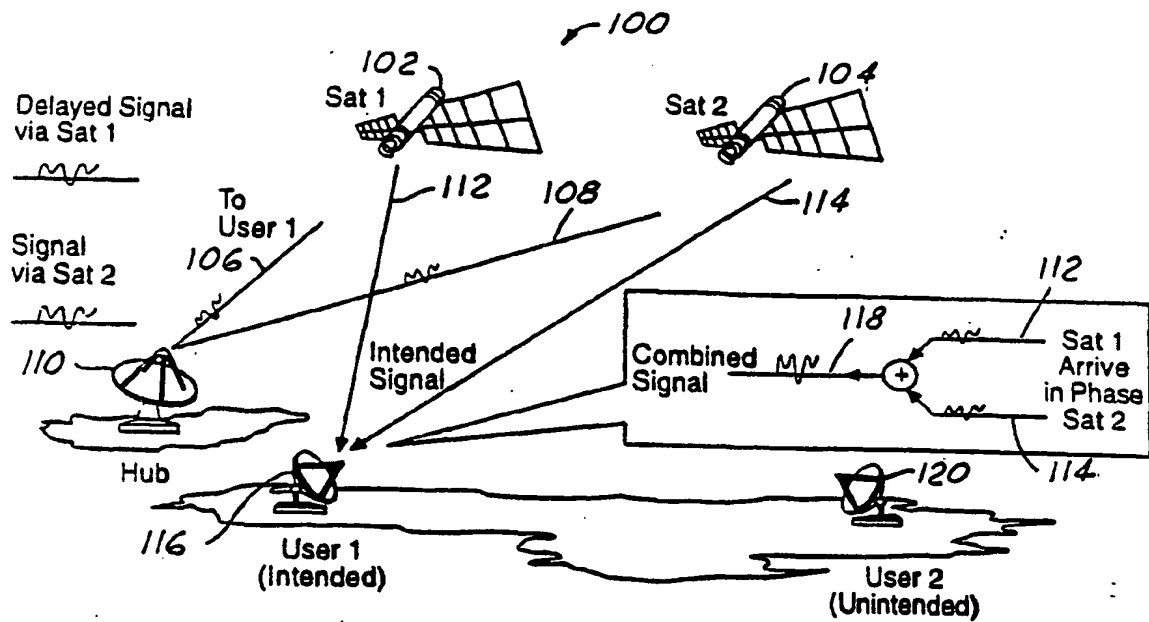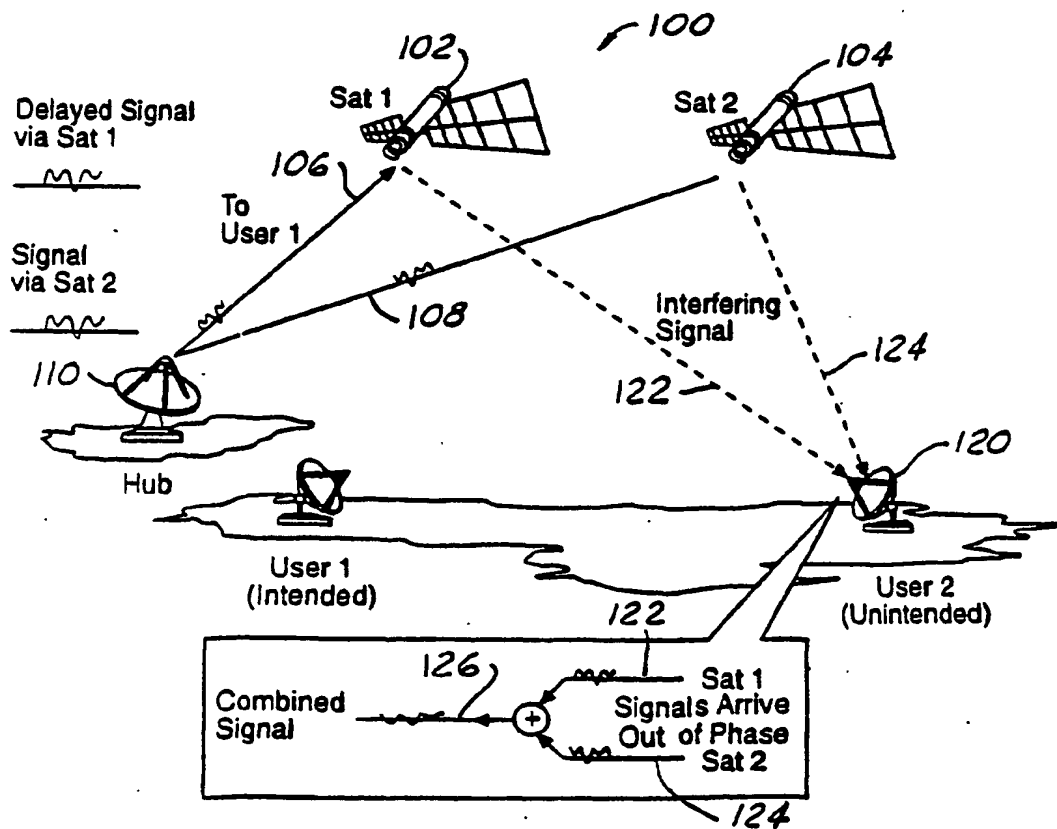BEAMS POINT TOWARD SATELLITE

MULTIBEAM ANTENNA

TO RADIATORS

FIG.2

FIG.3

FIG.4

FIG.5

4/5

FIG.6

FIG.7